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Knowledge-based inference making for reading comprehension: What to teach and what not¹

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Abstract

It is easy to see that texts do not tell the whole story. Rather, they can be seen as detailed instructions to readers about which background knowledge they should activate and combine into a coherent mental model. So readers will have to add knowledge and link information from the text with relevant background knowledge. In many cases, the text does not exhibit any explicit signal that something is missing, and the reader has to make an inference to maintain the global coherence of the text. It has been shown that students with poor comprehension sometimes fail to make such knowledge-demanding inferences because they fail to activate the relevant knowledge.

In a first study, 11-year-old students were taught to activate relevant background knowledge by means of graphic organisers: some boxes had to be filled with information from the text, while others were to be filled with information from the reader's background knowledge. The teaching turned out to be highly effective not only for inference making in reading, but also for reading comprehension in general.

Two limitations are discussed. First, teaching to activate background knowledge is probably much more important for comprehension of *expository* texts than for typical narrative texts. This is so because comprehension of expository texts depends much more on background knowledge that is abstract, *not* first hand experience and thus not immediately available. Second, an *over-reliance* on background knowledge may

¹ Note: An earlier version of this paper was presented at a workshop on inference making at the College of Education, National Chung Cheng University, 28th of March 2014.

stand in the way for learning something new that is in conflict with prior knowledge or beliefs.

It is further suggested that the teaching of knowledge activation for inference making may be integrated into the teaching of common text structures such as cause-consequence, compare-contrast, and problem-solution.

The reader's contribution

In a famous scene from *War and peace* by Tolstoi, the very young woman Natasha Rostova and her family are at the opera. Natasha is in love and does not engage in the action:

“In the second act there was scenery representing tombstones, there was a round hole in the canvas to represent the moon, shades were raised over the footlights, and from horns and contrabass came deep notes while many people appeared from right and left wearing black cloaks and holding things like daggers in their hands. [...] behind the scenes something metallic was struck three times and everyone knelt down [...]” (Tolstoj, *War and peace*, 1869, Book 8, chapter IX)

Natasha's experience is raw in the sense that she sees and hears everything in an extremely literal manner. She registers that “shades were raised over the footlights”, not the significance – that the scene takes place at night. She registers that people on the stage hold “things like daggers” in their hands, not that they are meant to evoke the image of a procession carrying crosses. Natasha is emotionally detached from the opera because her emotions are somewhere else. And because she does not engage emotionally in the opera, she cannot make sense of the events. The actions do not form a coherent mental representation: a sombre, nightly procession at a graveyard. They remain disconnected props and movements.

Most inferences require that the spectator, or reader, *contributes* something. The spectator or reader should contribute knowledge – such as knowledge of the significance of religious symbols and conventions: crosses (“things like daggers”), church bells (“something metallic”), a call to prayer (“three strikes” of the church bell), and prayer (“everyone knelt down”).

Natasha's experience is an example of what it may be like to read a piece of fiction without making essential inferences. In her case, she does not activate knowledge and emotional experiences because her emotions are already preoccupied. Because she

does not activate the relevant knowledge and emotions, she cannot form a coherent mental model of the opera.

Even very simple texts, like the following, require that the reader activates and uses relevant knowledge to make a coherent mental model of the text:

Carla slipped in the banana peel. George called for help immediately.

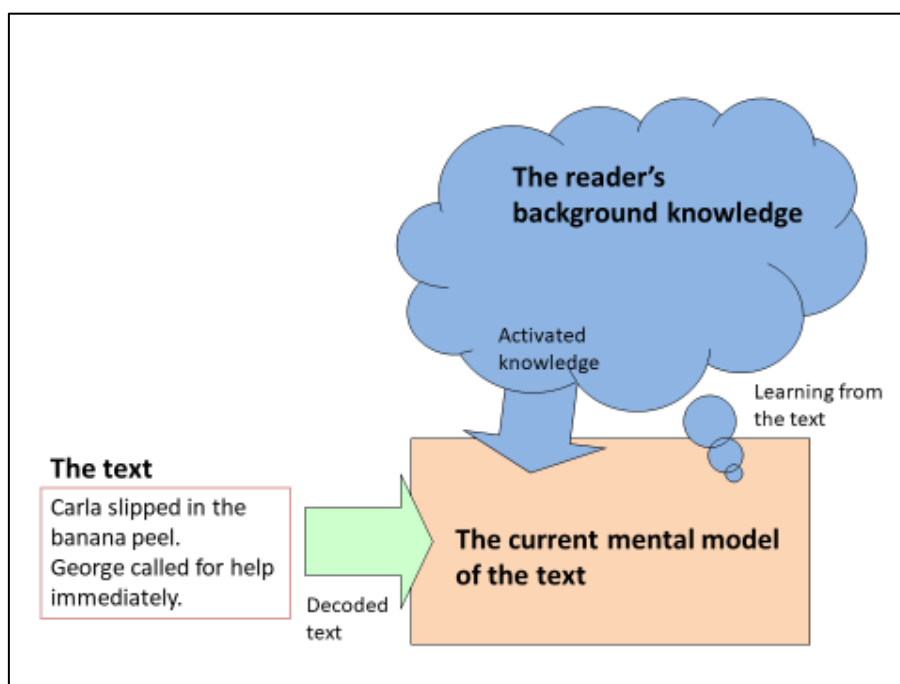


Figure 1. The construction of a coherent mental model of the text requires activation of relevant background knowledge

In order to make the two sentences cohere, the reader must activate relevant background knowledge:

Slipping – and thereby falling – can cause serious injuries.

Based on the text and the activated background knowledge, the reader will have to *infer* that Carla had a serious injury. George was sufficiently close and responsible – perhaps he already knew Carla – to notice and to evaluate Carla's needs in the situation. And he found reasons to call for help immediately. The reader can only guess, by means of an *elaborative* inference, what may have happened to Carla. Did she break something, did she hit her head? It must be something serious since George had to call for help immediately. Likewise, the reader may assume that George used his phone to call for an ambulance. Although unlikely, the reader may imagine much

more than that, e.g. where the accident took place, the gathering crowd of onlookers at the scene etc. The reader may even infer that the author of the example has had training in linguistics, because examples with mishaps and accidents are common in linguistics (to attract the attention of the students).

In contrast, the inference that Carla hurt and injured herself is a *necessary* inference (see Oakhill, this volume). It is necessary in the sense that it is required to make the two sentences cohere. In this example, the reader has to make a *global coherence* inference. Such inferences are necessary when there are no signals in the text, such as personal pronouns, connectives or other cohesive ties (Halliday & Hasan, 1976) to indicate that the reader has to contribute something. Signalled inferences are called *local cohesion* inferences (see Oakhill, this volume).

Global coherence inferences can be tricky because they are *not signalled* in the text. Texts rarely have markers, such as (...), to indicate that something has been left out for the reader to imagine. It is usually just taken for granted that the reader will spot the comprehension gap, activate relevant background knowledge and use it to link up the different parts of the text in a manner that is both plausible, relatively simple and makes good sense of the text.

Against this background, it is not surprising that there is good evidence that inference making plays a central and possibly causal role in reading comprehension. Both longitudinal studies (with control for earlier levels of reading comprehension) (e.g. Oakhill & Cain, 2012), and experimental training studies have provided such evidence (e.g. Yuill & Oakhill, 1988; McGee & Johnson, 2003) (see also Oakhill, this volume).

The need for background knowledge – and the activation of it

Texts become impenetrable when they require knowledge-based inferences but the knowledge is unavailable to the reader. This is a typical situation when students fail to understand expository texts (e.g. Best, Floyd, & McNamara, 2008; Kendeou and van den Broek, 2007), because expository texts are generally more knowledge demanding than narratives.

In a seminal study, Kate Cain, Jane Oakhill and colleagues (2001) investigated the role of background knowledge in inference making in 7-8 year-old school children. The authors were concerned with children who failed to comprehend texts even though they had no problems with word decoding or with the relevant background knowledge. The authors made sure that all the children in the study had the required

background knowledge. They did so by teaching each of the children the necessary background knowledge for a text about an imaginary planet called Gan.

Here are four items from *the knowledge base* (12 items) that was taught to criterion:

- The ponds on Gan are filled with orange juice,
- Bears on Gan have bright blue fur,
- The flowers on Gan are burning hot,
- The turtles on Gan have ice skates attached to their feet

Here is a section of one of *the texts* that the children read and were asked questions about:

Tane and Dack took their coats out of their bags and put them on. Their coats were made of bear's fur. Before long the path was icy and slippery. Tane and Dack kept falling on the ice. They saw two turtles ahead of them on the path. "I wish I was a turtle," sighed Dack.

And here are some of the questions that were asked after each child had read the text above:

- What did Dack wish? ... • Why?
- What colour was Tane's coat?

Even though all children had the same background knowledge, children with text comprehension difficulties still failed to answer as many inference-demanding questions about the text as the other readers did. An inspection of the responses of the poor comprehenders indicated that they did not draw upon their knowledge. They did not *activate* the relevant background knowledge by themselves.

Given this result, it is a central concern for educational research into reading comprehension to find ways in which poor comprehenders may learn to activate relevant background knowledge for inference making.

Inference making is typically taught in dialogues between teachers and students. Ideally, teachers ask inference-demanding questions and discuss answers with the students. For the text about the planet Gan, an example of such a question could be "why do gardeners on Gan wear gloves?" (expected answer: because the gardeners need protection from the burning hot flowers). In reality, teachers may not ask such questions very often.

Ask inference demanding questions for this text

Most of the inhabitants of Oatby were born there. The place had almost everything: a grocery shop, a pub, a village green for football and little children's feet, a school, a health centre, even a TV and phone shop. But there were no cafes, and few educational opportunities. The number of people was dwindling. House prices were dropping. In an attempt to counteract this development, the town council decided to get in touch with Center Parcs and other holiday centres. The spelling ability of future generations might be endangered, but that would have to be dealt with in due course. (From Oakhill, Cain & Elbro, 2014).

(Some suggestions are given at the end of this paper).

How background knowledge fits in

It is easy to see that background knowledge is necessary for most inferences. The information from the text is not enough on its own, it has to be supplemented by information from the reader. It is also clear that some poor readers have comprehension difficulties because they fail to activate their background knowledge and apply it to form a coherent mental model of the text. So far so good.

The real complexity arises with the question about *how* exactly the reader's background knowledge connect with the information from the text. There is not one type of connection that fits all purposes. Perhaps this is one important reason why inference making and the teaching of it remains obscure to both students and their teachers.

There are at least three types of general logic involved in inference making:

First, there is *deduction*: a category or general principle is mentioned in the text, and the reader infers something that is implied in the category or principle. For example, if a horse is mentioned, it is reasonable to expect it to have four legs; or if someone falls, the inference is that the person will hurt him- or herself. The inferred contents *follow* from general knowledge of horses and falling. Obviously, the necessary general knowledge must be present. But at least the topic is explicitly mentioned in the text.

Second, there is *induction*: details mentioned in the text lead to a well known category or a general principle. For example, the animal on the farm has four legs and produces 15 litres of milk a day – makes it likely that it is a cow. Or the text may detail the many bruises on the woman's knees and elbows and how she walks with

difficulty, and the reader may infer that the woman has had a fall (or several). This is a more difficult type of inference making because the relevant category or general principle is not mentioned. The reader will have to activate the cow and a fall on his or her own.

Third, there is *abduction*: details mentioned in the text are explained by the best available hypothesis. For example “Carla did not notice the banana peel. George called for help immediately”. The best available hypothesis may be that Carla slipped and hurt herself so badly that she needed medical attention (as discussed above).

Abduction is similar to induction in that the reader has to set up the explanatory (linking) concept or principle on his or her own. But it differs from induction because the reader cannot just activate a general category or principle. The reader has to construct a new mental model that can link up the details of the text; it is not enough just activate a ready-made frame. Clearly, this is the most demanding type of inference making of the three.

The use of graphic organisers to visualise the contribution from the reader’s background knowledge. A training study

So far, it should be clear that the reader has to contribute background knowledge to reading comprehension. Background knowledge is needed for most inferences during reading, and inferences are necessary for building a coherent mental model of a text. In addition, even a cursory analysis of the role of background knowledge in inference making demonstrates the intricacy of the relationship between information from the text and from the reader.

This complexity of inference making raises serious questions for the teaching of reading comprehension. Two core questions are: How can the teacher help students activate relevant background knowledge? And how can the teacher help students form the right inferences using information from both the text and their background knowledge?

One possibility is to use graphic organisers to explicate the relevant background knowledge and how it links in with the text (Figure 2).

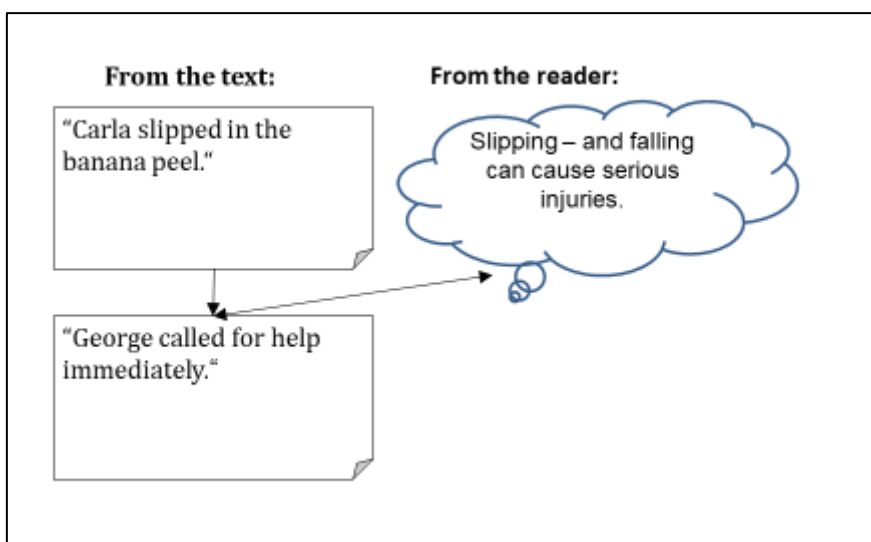


Figure 2. Teaching inference making using graphic organisers to visualise the contribution from the reader's background knowledge.

Graphic devices can be used to put into words and to highlight the information that the reader has to contribute. At the same time, the relation between the reader's contribution and the text can be signified by means of the positioning of the text boxes and the arrows between them.

Graphic organisers (models) are extremely efficient in teaching reading comprehension (Pearson & Fielding, 1996) and listed among the seven types of instruction recommended by the National Reading Panel (2000). Graphic organisers use spatial orientation (and arrows and other graphic devices) to indicate logical relations. Obviously, students have to be familiar with the syntax of graphic organisers to make good use of them, but the meaning of most organisers is completely transparent to students.

The use of graphic organisers to teach inference making was studied and recently reported for the first time (Elbro & Buch-Iversen, 2013). The study, which was carried out in the Stavanger area in Norway, involved 236 students (average age 11:2 years) in 16 intact classes. The classes were randomly assigned to either an experimental condition (10 classes) or a teaching-reading-as-usual control condition (6 classes). All classes were taught by their usual teachers.

Teaching in the experimental condition focussed on expository texts and causal inferences. The teaching materials were written for the study and consisted of 15 texts of 100 to 200 words. Each of the 15 texts had inference-demanding questions and support in the form of graphic organisers. A very simple example is shown in Figure 3.

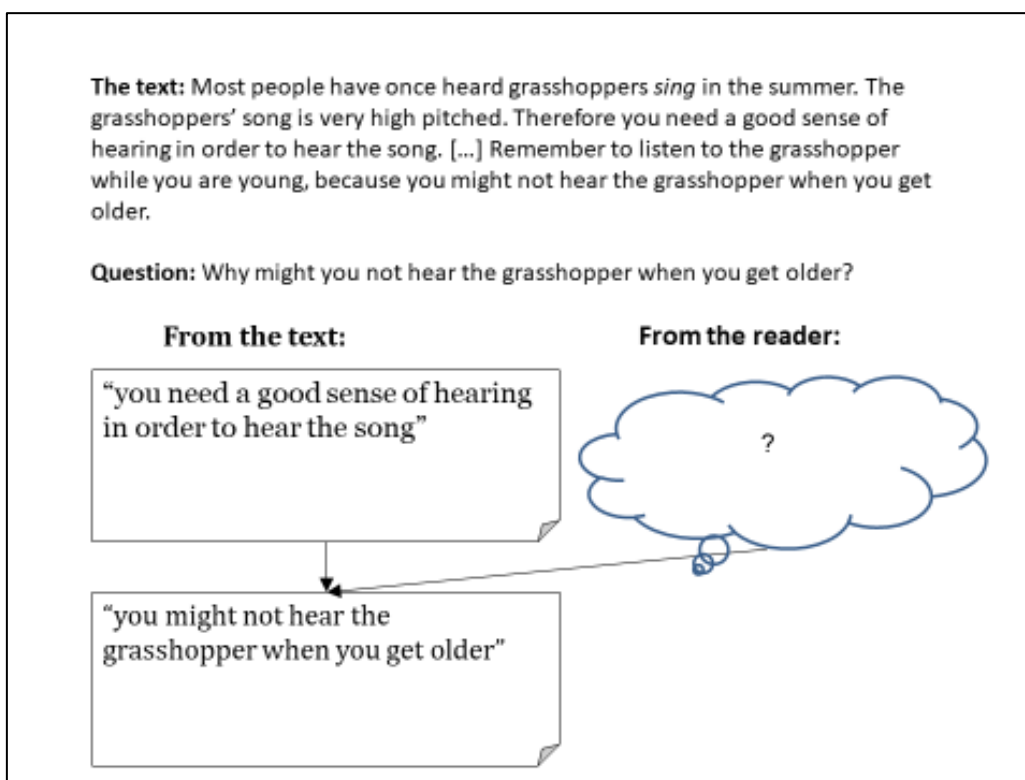


Figure 3. An example of the materials used in the teaching of inference making. Information from both the text and the reader's background knowledge is needed to answer the question: Why might you not hear the grasshopper when you get older?

The experimental program lasted 8 sessions of 20 minutes each, though some classes spent up to 40 minutes on some sessions. In the course of the 8 sessions the support from the graphic organisers was gradually diminished until, at the end, the students had to respond to inference-demanding questions just by thinking about what knowledge they had to bring to the task and how to fit it in with the text.

At the onset and by the end of the program, several measures were taken in both experimental and control classes. A measure of *the directly trained abilities* required answering inference-demanding questions about texts. This measure was made by the experimenters, and the texts were expository and the questions required global coherence inferences similar to those in the inference training. Inter-rater agreement and other measures of reliability were high. The direct training effect was remarkably high (Cohen's $d = .92$) following just 8 short sessions, and highly statistically significant even when analysed with class as the unit of analysis (nested in conditions).

Measures of maths abilities and motivation for reading were taken in order to detect and, if necessary, control for general expectancy and motivation effects.

However, neither the maths test (M5-test, Tornes, 1996) nor the Motivation for Reading Questionnaire (Guthrie, Wigfield, & VonSecker, 2000) showed any signs of an interaction between time and condition.

A possible transfer of the experimental teaching to general reading comprehension was measured with a Norwegian translation of the The Diagnostic Reading Analysis (DRA; Crumpler & McCarty, 2004). This test is not standardized in Norwegian, but it is a “standard” test in the sense that it is not experimenter devised and that it covers a broad range of text types and reading requirements. Half of the texts are narratives and the other half expository. Half the questions are literal and the other half are classed as either inferential/summative, predictive, or vocabulary questions, which all require some kind of interpretation. With this test, a medium to large transfer effect ($d = .69$) was found which was also highly significant.

A further indication of the efficiency of the program was found in a follow-up test of a subset of the participants (2 + 2 classes) 5 weeks after the completion of the training. At this point, the students in the experimental group still maintained their advantage in reading comprehension over the controls.

The robustness of the training program was studied with respect to the effects of both student variation and variation in the implementation of the program. The general finding was one of high robustness. The individual student gains in reading comprehension did *not* depend on students’ word decoding and vocabulary at pre-test, students’ gender, or non-verbal IQ. Neither did the degree of completion of the program nor the teachers’ class management (time taken for class to settle down to work) explain variance in the outcomes of the program. The only positive correlates with class gains were longer sessions and fewer students in the class.

In sum, this first training study provided evidence that

- graphic organisers can be used to train the activation and use of background knowledge for inference making with expository texts,
- this training can have positive transfer effects to text comprehension in general, and to expository text comprehension in particular, and
- the effects can be robust and sustained.

Limitation 1: not all sorts of background knowledge need activation

On the basis of the first study it was impossible to tell whether the improvements in inference making were brought about mainly by the emphasis on the readers’ contributions, or the graphic organisers were an essential component. Given the positive results of the above study, Daugaard and Elbro (2012) conducted a second

study of inference training in an attempt to separate the effects of graphic organisers from the effects of the other parts of the inference training. Participants were 245 students (aged 12-13 years) from 18 classes. The participants were randomly allocated (by class) to one of three experimental conditions or a teaching-as-usual control condition. Classes in three experimental conditions were taught either inferences with graphic organisers (as in the first study), inferences only, or graphic organisers only (with few requirements for inferences). The experimental programs took up an average of only 7 lessons (over 4 weeks). The measures of the direct training effects and the transfer effect to general reading comprehension were the same as in the first study (translated from Norwegian into Danish).

In sharp contrast to the first study, this second study showed no direct training effect on inference making; no significant differences were found between gains in the experimental conditions and the control condition.

The lack of significant training effects may to some extent be explained by a less sensitive design with smaller groups and shorter training. However, one difference stands out: In the second study, more than two thirds of the *texts were narratives*. Since the type of text (expository or narrative) was not an experimental variable in either study, it is not possible to draw any firm conclusion about the cause of the very different outcomes of the two studies. However, there are good reasons to suspect that the type of text matters for inference making – or more precisely for the kind of knowledge that the reader has to bring to the task (see table 1).

Table 1. Background knowledge – type and availability depends on text genre

The text:	The reader's background knowledge	Availability
Narrative	Personal, first hand experience, e.g. 'It hurts to slip and fall, slipping can cause serious injuries'.	Always, immediate
Expository	Impersonal, abstract knowledge, e.g. 'Hearing of high-pitched sound deteriorates with age'.	Not always, requires search

In narratives, coherence is often maintained by human emotions and the goals of the characters. The 'sub-text' that drives the actions and what is said is motivated by human emotions and ambitions. In the simple banana-peel example the relevant background knowledge is very much shared between all human beings: you can seriously hurt yourself if you slip and fall. The text draws on human experience that is

always and immediately available. Hence, there is no need for encouragement to activate the relevant knowledge, i.e. experience. Similarly, in the much more complex initial example from the opera, the relevant experience is one that anyone who have been in love carries with them: love makes the rest of the world insignificant and uninteresting.

Conversely, the relevant knowledge for making coherence inferences with expository texts is mostly impersonal and abstract. Schoolchildren have no direct, personal experience with the types of hearing loss that are typical in adults and old age. Indeed, students have no direct, personal experience with most topics of the expository texts that are common in school. So these are precisely the types of texts where the relevant background knowledge may either be lacking or not readily available. In the case of knowledge-demanding coherence-maintaining inferences, there is not even a clear linguistic signal in the text that will prompt the reader to activate the relevant background knowledge. Hence, it is not surprising that some students need help to activate the relevant background knowledge with expository texts. The relevant knowledge for inferences in narratives, on the other hand, is mostly immediately available as a common human experience.

Limitations 2: Background knowledge can be misleading

Background knowledge is indispensable for most cohesion-maintaining inferences during reading. However, it is not a good idea to teach students indiscriminately to make more use of their background knowledge. Here is an example to illustrate why:

Try to answer the following three questions about fire alarms (without access to the instructional leaflet that the questions were created for):

1. Where is it recommended that you place the fire alarm in a two-bedroom flat if you have only one alarm?

- (a) near where you spend most of the time (the lounge)
- (b) near the main entrance (the escape route)
- (c) near where you sleep (the bedroom)
- (d) near inflammable things (the kitchen).

2. Is it OK to put a fire alarm up on a wall?

- (a) yes, but not above a radiator
- (b) yes, about half-way between floor and ceiling
- (c) yes, about a foot from the ceiling

(d) no, smoke rises towards the ceiling.

3. According to the text, the fire alarm should be tested

- (a) once a year
- (b) once a week
- (c) when the battery is replaced
- (d) twice a year

In a study of the uses of background knowledge for studying, university students were asked to try to answer the above (and other) questions about texts that they had *not* read (Elbro & Arnabak, 2002). For question 1, the vast majority of the students chose option (c): “where you sleep”. This is a reasonable answer given that most people killed in fires suffocate during sleep. This was also the correct answer following the instructional leaflet. So in the case of this question, general background knowledge appeared to be very helpful.

For question 2, the students had no real preference. Following the instructional leaflet, the correct answer is (c) “yes, about a foot from the ceiling”, which was the answer that was chosen by about a fourth of the students. Obviously, there is common knowledge about smoke and fire, such as smoke rises. But apparently, the shared common knowledge did not point more directly towards one answer than the others. Hence, with this question, shared background knowledge appeared to be neutral.

It was quite different for question 3, for which the correct answer was (b) “once a week”. This was clearly much more frequent than the vast majority of the students thought. Common background knowledge, e.g. about the expected lifetime of batteries, was *probably misleading* in this case.

Obviously, if readers consequently insisted on the primacy of their background knowledge, they would be practically unable to learn anything new. So religiously following one’s background knowledge is counterproductive for learning from text.

The above mentioned study went a step further and looked into the importance of being able to answer all three types of questions, i.e. both those for which common background knowledge is supportive, those that are rather uncorrelated with common background knowledge, and the tricky ones for which common background knowledge may be misleading. In the study, a group of 132 adults studying for the equivalent of a school-leaving exam were asked to read texts and answer multiple choice questions about them. The questions were divided into the three groups

mentioned above depending on whether common background knowledge (among university students) was supportive, neutral, or misleading.

Multiple regression analyses of the *exam marks* (in Danish language and literature) of the 132 adults indicated that all three types of questions contributed significant, unique variance to the marks. This result suggests that a high exam mark was more likely when an adult was both able to apply common knowledge when it was helpful and able to let the text overrule common knowledge when there were good reasons in the text to do so. Or put another way: some adults were *inactive* (or lacking in background knowledge) and brought little knowledge to the reading comprehension task, while others were *unteachable* because they insisted too hard on the knowledge that they brought to the reading task, and some were possibly both inactive and unteachable with different texts.

Conclusions

The use of background knowledge has to be balanced. If the reader insists on his or her prior knowledge and beliefs, they may block the learning of new insights that are partly or totally in conflict with prior knowledge. Clearly, such a block is an impediment to studying and learning from texts. However, this paper has not touched upon the difficult question about exactly *when* the reader should let the text dominate over their prior knowledge and beliefs and when they should not. Neither has the paper dealt with the question about how to teach students answers to this intricate question.

The purpose of this paper was more modest, namely first to inquire into how background knowledge is used for a necessary but rather specific purpose in reading, namely to fill gaps between bits of explicit information in texts. These inferences are here termed global coherence inferences (see also Oakhill et al., 2014). They are necessary for the reader to form a coherent mental model of the meaning of the text, but they are not explicitly signalled in the text.

The second purpose of the paper was to give an example of how teaching may support such global inferences. In the example, students were made aware of their own contribution to the inferences by means of graphic organisers. The graphic organisers would highlight not only the background knowledge that the students brought into the inference but also how it fitted in with the literal information from the text. A first empirical training study indicated that such teaching was indeed helpful not only for inference making but for reading comprehension in general.

However, a second empirical training study failed to find an effect of a very similar experimental teaching with narrative texts. One simple reason may be that the necessary background knowledge is readily available in the case of the typical inferences made during reading of narratives, whereas expository text draws on background knowledge which is much less personal and less rooted in experience and hence not immediately available.

So where do we go from here? First of all, the successful teaching experiment with graphic organisers for activation of background knowledge needs replication. It would be valuable to explore different ways in which background knowledge may be activated for inference making. Perhaps the success of the program was not so much a function of the graphic organisers as the careful pairing of information from the reader with information from the text.

Another important issue is whether there is a link between the general logical (macro) structure of texts and the types of inferences they demand. And if there is whether differently structured texts require different teaching. For example, most of the texts in the first teaching experiment had a *causal* structure, i.e. they contained various causal chains, as reflected in the examples throughout this paper. The typical function of background knowledge in such texts is to provide causes or links in a causal chain.

Conversely, texts with a basic contrast-compare structure would typically require background knowledge for to fully appreciate contrasts and comparisons that are only implicit. For example, if a particular fridge is praised as “quieter”, or Freud characterises women as empathic, it is implied that some other fridges are noisier, and that men are not particularly empathic. The point in the context of inference making is that the ground for comparison is far from always specified (fridges in general, the two genders), so the reader will have to activate the relevant ground for comparison themselves.

Promising results have been made in making even young schoolchildren aware of basic text structures, such as cause-consequence, contrast-compare, problem-solution etc. (e.g. Williams et al., 2009). An unexplored possibility is that the activation of relevant background knowledge for inference making could be taught within the context of each of these text structures.

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Some inference-demanding questions about the Oatby text (text box 2):

- What size town is Oatby?
- Why was the number of people in Oatby going down?
- Where would you go to buy milk on a Sunday in Oatby?